CONCLUSION

The high dependency between parameters cannot be proved for numbers of parameters, although from geological point of view these causal relationships can be explained. On the other hand, previous studies have indicated the significant influence of those parameters to flow characteristics.

Looking closer to those equations, it is shown that easier to estimate parameters and flows with very limited basic data to some degree of acceptable error. These are only good in cases of ungauged catchments, but are not recommended for gauged catchments.

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REFERENCES


ACTIONS TAKEN BY PEDESTRIANS AND DRIVERS TO AVOID ACCIDENTS

Siti Malikhamah¹

ABSTRACT

A small number of traffic conflicts or potential accidents lead to accidents. Most of road users involved in conflicts do evasive actions to avoid accidents. A research was carried out to examine the actions taken by road users to avoid pedestrian-vehicle collision or accidents. Information on pedestrian-vehicle conflicts, pedestrian and driver speeds were obtained synchronously through a combination of direct observations, video analysis, and analysis on tube and loop detectors output. It was found that pedestrians walk, jog, or run while drivers decelerate to avoid a collision. The decelerations became harder at a point around 25 metres from the stop line and the maximum value was 8.9 m/s².

INTRODUCTION

Traffic conflict was defined as:

either an event that would have led to a collision if both road users had continued with unchanged speeds and directions or a near-miss situation where at least one of the road users acts as if there were collision course (Hyden, 1987).

From the definition above it can be mentioned that if both road users involved in conflicts do not do any evasive actions a collision or an accident will occur. Hyden (1987) described that a small number of conflicts lead to accidents because the available margins are not big enough. Many pieces of research have been carried out to investigate the evasive actions taken by drivers but very little was undertaken for conflicts involving pedestrians. Therefore a research has been carried out aiming at investigating the evasive actions taken by drivers and pedestrians to avoid accidents at Pelican Crossings and the results are presented here. Older and Spicer (1976) used precautionary braking as an indicator to determine the severity of conflicts. Their method was criticised by Hauer (1978) and Allen et al (1977) because evasive action determined by observers introduced a subjective element. The research reported here determined the actions taken by road users objectively by measuring their speeds. In more detail the objective of the research was to investigate the speeds of pedestrians and the speeds and decelerations of vehicles when they were involved in conflicts.
MEASUREMENTS

Data collection was carried out at a very busy Pelican Crossing at Leeds, UK to get information on pedestrian-vehicle conflicts, pedestrian speed/driver speeds and decelerations. The information was collected synchronously through a combination of direct observation, video analysis, and analysis of tube and loop detectors' output. The safety indicator used was Post-Encroachment-Time (PET). PET is the time between the moment that the first road-users leaves the path of the first (Horst, 1990). The layout of the cameras, loops and tubes is presented in Figure 1.

![Diagram of camera, loop, and tube layout](image)

**Figure 1. The Lay Out of Cameras, Loops and Tubes for Data Collection**

Each pair of the tubes was put 1 metre apart and all of the tubes and loops were put at certain distances from the stop line. The x-y loops were standard loops installed at 39 m (L39), 25 m (L25), and 12 m (L12) from the stop line respectively. The first pair of tubes were put at 57-56 metres (T57); the second pair of tubes (T122) were put on the left of the loop or L12; the third tubes were put at 4-3 metres (T4). By so doing driver behaviour was tracked at L57, x loop (L39), y loop (L25), z loop (L12) and T12, and T4. The tubes and loops were connected with data loggers. The data obtained from the data loggers were analysed to get information on vehicle speeds using Equations 1 and 2 below:

$$\text{Speed}_{ij} = \frac{\text{Length}_{ij}}{\text{Duration}_{ij}}$$ (1)

where:

- \(\text{Length}_{ij}\) = combined length (length of vehicle + loop field length) of vehicle \(i\), metres
- \(\text{Speed}_{ij}\) = speed of vehicle \(i\) across L12, m/s (obtained from T12)
- \(\text{Duration}_{ij}\) = how long vehicle \(i\) occupied L12, seconds (obtained from L12)

$$\text{Speed}_{i} = \frac{\text{Length}_{i}}{\Delta t_i}$$ (2)

where:

- \(\text{Speed}_{ij}\) = speed of vehicle \(i\) across Loop \(j\)
- \(\Delta t_i\) = time occupancy of vehicle \(i\) crossing Loop \(j\), seconds (obtained from Loop \(j\))

After the speeds of each vehicle across T57, L39, L25, L12 and T4 were obtained, the decelerations across the subsequent points were calculated using Equation 3 by assuming that there was constant deceleration between 2 points:

$$\text{Deceleration}_{ik} = \frac{V_k - V_j}{t_{jk}}$$ (3)

where:

- \(\text{Deceleration}_{ik}\) = deceleration of vehicle \(i\) between point \(j\) and \(k\), m/s²
- \(V_k\) = speed of vehicle \(i\) at point \(k\), m/s
- \(t_{jk}\) = how long to travel from point \(j\) to point \(k\) for vehicle \(i\), seconds

The deceleration was calculated with decelerations calculated using Equations 4 and 5:

$$\text{Deceleration}_{ik} = \frac{V_k^2 - V_j^2}{2S_{jk}}$$ (4)

where:

- \(S_{jk}\) = distance between point \(j\) and \(k\), metre

$$\text{Deceleration}_{ik} = \frac{2S_{jk} - V_j^2}{t_{jk}}$$ (5)

The decelerations were exactly constant when the deceleration values obtained from Equations 3, 4 and 5 were exactly the same. When the decelerations were not constant the deceleration values obtained from Equation 3 were always between the...
the use of Equation 3 to calculate deceleration in this research. It was found that the ratio between the mean decelerations calculated using Equation 3 and those calculated using the other two for all vehicles was around 0.8 and 1.2.

Pedestrian speeds were calculated using Equation 6.

\[ V_p = \frac{7.2}{(t_{p2} - t_{p1})} \]  

Where:
- \( V_p \) = pedestrian speed, m/s
- 7.2 = the road width, m/year
- \( t_{p2} \) = the time a pedestrian arrived at the far-side kerb, second
- \( t_{p1} \) = the time a pedestrian committed to cross the street, second.

RESULTS AND DISCUSSIONS

Pedestrian Speeds

This study found that pedestrian mean crossing speed was 1.77 m/s. This is almost similar to the mean crossing speed of young people studied by Griffiths et al. (1984), i.e. 1.72 m/s. The pedestrian crossing speeds found in this research are much higher than those found by Austin and White (1997) and Sjostedt (1967). The first study measured walking speed only and found that the median pedestrian speed was 1.4 m/s (compared to 1.7 m/s found in this study as shown in Figures 2). The higher speeds found in this study may be because that Austin and White (1997) do not include running speed.

![Pedestrian Speeds](image)

**Figure 2.** Pedestrian Crossing Speeds

Sjostedt (1967) found that the mean crossing speed of adult and elderly persons

As seen in Table 1 pedestrian mean speed was higher for pedestrians involved in conflicts (1.9 m/second compared to 1.6 m/second). However, this does not mean that there is no pedestrian who is not involved in any conflicts walking fast or running. Around 10 per cent of these pedestrians walked fast or ran at speeds of more than 2 m/s.

From the video it has been learned that there are 3 main reasons why some pedestrians stepping-off the kerb during period D walk very fast or run:

- a) The pedestrians wanted to catch a bus (there was a bus stop at the other side of the road).
- b) The pedestrians wanted to catch up with their friends.
- c) The pedestrians were in a hurry; (but the reasons why they were in a hurry were unknown).

The speeds of pedestrians getting involved in conflicts were higher than the speeds of those who do not. The reason was some pedestrians tried to avoid pedestrian-vehicle collisions by walking fast or running. In other words, the pedestrians made some effort to make PEIT high. It was also found that the speed standard deviation was higher for pedestrians involved in conflicts (0.5 compared to 0.3). Pedestrians getting involved in conflicts have more varied speeds because their speeds were influenced by the severity of conflicts and their perception of conflicts.

<table>
<thead>
<tr>
<th>Statistics and Period</th>
<th>Pedestrian Crossing Speeds (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When not Involved in Conflicts</td>
<td>1.56</td>
</tr>
<tr>
<td>Mean</td>
<td>0.28</td>
</tr>
<tr>
<td>Standard Deviation (SD)</td>
<td>1.03</td>
</tr>
<tr>
<td>Minimum</td>
<td>2.96</td>
</tr>
<tr>
<td>Maximum</td>
<td>2.96</td>
</tr>
<tr>
<td>2. When Involved in Conflicts</td>
<td>1.93</td>
</tr>
<tr>
<td>Mean</td>
<td>0.52</td>
</tr>
<tr>
<td>Standard Deviation (SD)</td>
<td>1.13</td>
</tr>
<tr>
<td>Minimum</td>
<td>4.26</td>
</tr>
<tr>
<td>Maximum</td>
<td>4.26</td>
</tr>
<tr>
<td>3. All Situations</td>
<td>1.77</td>
</tr>
<tr>
<td>Mean</td>
<td>0.47</td>
</tr>
<tr>
<td>Standard Deviation (SD)</td>
<td>1.03</td>
</tr>
<tr>
<td>Minimum</td>
<td>4.26</td>
</tr>
</tbody>
</table>
Vehicle Speeds

The main aim of the analysis on vehicle speed is to find out whether drivers decelerate when there is a pedestrian conflict and when they start to decelerate. As seen in Table 2, 57% of the cars in pedestrian-vehicle conflicts accelerated between T57 and T139, 49% per cent cruised between T139 and T25, 98 per cent decelerated between T25 and T12, and there were similar proportions of decelerations and accelerations between T12 and T4 (42 per cent compared to 41 per cent). It was also found that the percentage of decelerating at a rate above 3 m/s² was higher between T25 and T12, i.e. 35 per cent compared to 11 per cent between T57 and T139 and 11 per cent also between T139 and T25; and the smallest percentage (4 per cent) was found between T12 and T4. According to Williams (1977), the mean deceleration rate accepted by drivers is around 3.0 m/s². Horst (1990) and Bonsall, et al (1992) also determined a deceleration of 3 m/s² as a threshold between normal and abnormal deceleration. This deceleration is believed as the threshold of a comfortable rate. The highest decelerations were far more than this threshold, i.e. 8.5 m/s² which happened between T25 and T139, and 8.9 m/s² between T139 and T12. The deceleration mean rates were, 1.2 m/s² (T57 - T139), 2.9 m/s² (T139 - T25), 2.6 m/s² (T25 - T12), and 1.2 m/s² (T12 - T4). The mean acceleration rates (including acceleration and cruising) were +1.3 m/s² (T57-T139), +0.4 m/s² (T139-T25), +0.6 m/s² (T25-T12), and +0.4 (T12-T4). It was found that on average, vehicles accelerated between T57 and T139, cruised between T139 and T25, decelerated between T25 and T12, and finally either cruised, accelerated or decelerated between T12 and T4.

Table 2. Speeds, Decelerations and Accelerations of Vehicles Involved in Conflicts

<table>
<thead>
<tr>
<th></th>
<th>T57</th>
<th>T139</th>
<th>T25</th>
<th>T12</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>41</td>
<td>44.2</td>
<td>44.6</td>
<td>33.5</td>
<td>34.4</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>7.64</td>
<td>14.12</td>
<td>11.32</td>
<td>11.33</td>
<td>11.33</td>
</tr>
<tr>
<td>Min</td>
<td>20.00</td>
<td>2.30</td>
<td>5.00</td>
<td>0.0</td>
<td>0.02</td>
</tr>
<tr>
<td>Max.</td>
<td>60.00</td>
<td>56.67</td>
<td>72.09</td>
<td>31.00</td>
<td>72.00</td>
</tr>
<tr>
<td>Acceleration, m/s²</td>
<td>1.26</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.19</td>
</tr>
<tr>
<td>No of Accelerations*</td>
<td>5 (25)</td>
<td>35 (24)</td>
<td>0.0</td>
<td>61 (12)</td>
<td></td>
</tr>
<tr>
<td>No of Decelerations*</td>
<td>11 (11)</td>
<td>39 (25)</td>
<td>142 (48)</td>
<td>59 (41)</td>
<td></td>
</tr>
<tr>
<td>No of Jamming m/s²</td>
<td>16 (11)</td>
<td>71 (49)</td>
<td>1 (1)</td>
<td>32 (17)</td>
<td></td>
</tr>
<tr>
<td>No of Accelerations/3.0 m/s²</td>
<td>16 (11)</td>
<td>16 (11)</td>
<td>51 (33)</td>
<td>6 (1)</td>
<td></td>
</tr>
<tr>
<td>Acceleration and cruising, m/s²</td>
<td>1.39</td>
<td>1.34</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Mean</td>
<td>1.32</td>
<td>0.44</td>
<td>0.0</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.82</td>
<td>0.75</td>
<td>0.0</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td>5.37</td>
<td>4.29</td>
<td>0.30</td>
<td>2.99</td>
<td></td>
</tr>
<tr>
<td>Deceleration, m/s²</td>
<td>1.37</td>
<td>3.55</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Mean</td>
<td>1.16</td>
<td>2.88</td>
<td>2.62</td>
<td>1.23</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.96</td>
<td>2.14</td>
<td>1.67</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0.04</td>
<td>0.07</td>
<td>0.04</td>
<td>0.07</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 shows that 98 per cent of the drivers decelerated between T25 and T12. It means that drivers do take some action to avoid serious conflicts with pedestrians. The deceleration rates made varied, i.e. between 0.0 and 8.9 m/s². This indicated that the drivers were involved in conflicts with different levels of severity (apart from the fact that not every driver has the same expectancy and perception as described by Brown (1983)).

Three examples of driver behaviour when experiencing pedestrian-vehicle conflicts are presented in Figures 3-8. These figures give a better understanding of driver behaviour in relation to pedestrian-vehicle conflicts.

Figures 3 and 4 illustrate the behaviour of a driver involved in a pedestrian-conflict leading to a PET of 1.9 seconds. The vehicle accelerated between T57 and T139 from a speed of 45 km/h to that of 52 km/h; cruised between T139 and T25; reduced its speed between T25 and T12 until it reached a speed of 41 km/h; and finally decelerated again between T12 and T4 with a speed at the latest point around 20 km/h.

![Figure 3. Example 1: Distance-Time Diagram of A Vehicle Involved in PET = 1.9 seconds](image-url)
The second example is a vehicle involved in pedestrian-conflicts leading to a PET of 1.6 seconds and is illustrated in Figures 5 and 6. The vehicle's approach speed was higher than the first example, i.e., 55 km/h at T.7 and the vehicle accelerated so that it reached a speed of 65 km/h at L.39. The speed did not change before it decelerated at L.25 and the speed became 66 km/h at L.12. Finally, it accelerated until it reached a speed of 48 km/h at T.4.

Most drivers involved in pedestrian-vehicle conflicts react in such a way as described above: accelerate between T.57 and L.39, cruise or decelerate between L.39 and L.25, decelerate harder between L.25 and T.4, and finally decelerate, cruise or even accelerate between L.12 and T.4.
CONCLUSIONS AND IMPLICATIONS TO FUTURE RESEARCH

When there are pedestrian-vehicle conflicts, both road users take evasive actions to avoid a collision or an accident. Pedestrians walk faster or run and drivers decelerate. The decelerations usually become harder at a point around 25 metres before the stop line. The information on how drivers react, in this case how they change their speeds, when involving in conflicts at Pelican crossings can be used to develop a method to monitor safety at Pelican crossings. In order to determine the severity of conflicts based on the road user behaviour models need to be developed to relate traffic conflicts and vehicle speeds and decelerations.

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